MEMORANDUM

4 October 2016

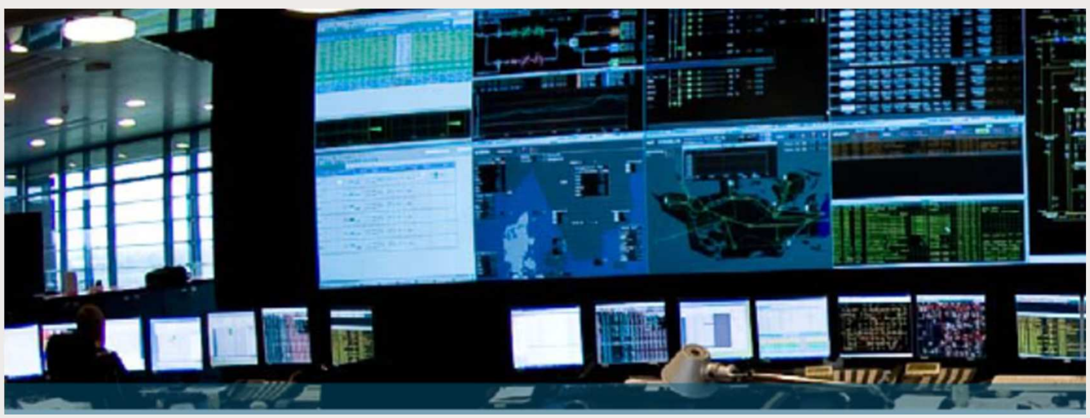
Energy scenarios for 2030

Doc. 15/08958-165

Why create scenarios?

Energinet.dk is active in a world where green energy is being increasingly phased in and legislative frameworks are, to a large extent, set at European level. Technological development is rapid and to some extent unpredictable, making it difficult to foresee changes in the energy system. The world is constantly changing, and Energinet.dk must ensure the Danish electricity and gas system continues to develop based on an assessment of what the future composition of energy and infrastructure will look like throughout Europe.

To create the foundation for the best possible transition, illustrate outcomes and ensure the value of the large investments to be made, Energinet.dk continuously analyses the development of the energy sector as a whole and separate parts of the energy system. For example, changes in areas such as fluctuating electricity generation, electrification, heating, transport, industrial process heat, green gas, fossil fuels and biofuels – both in Denmark and its neighbouring countries – have a major influence on the future electricity and gas infrastructure needs.



Contents

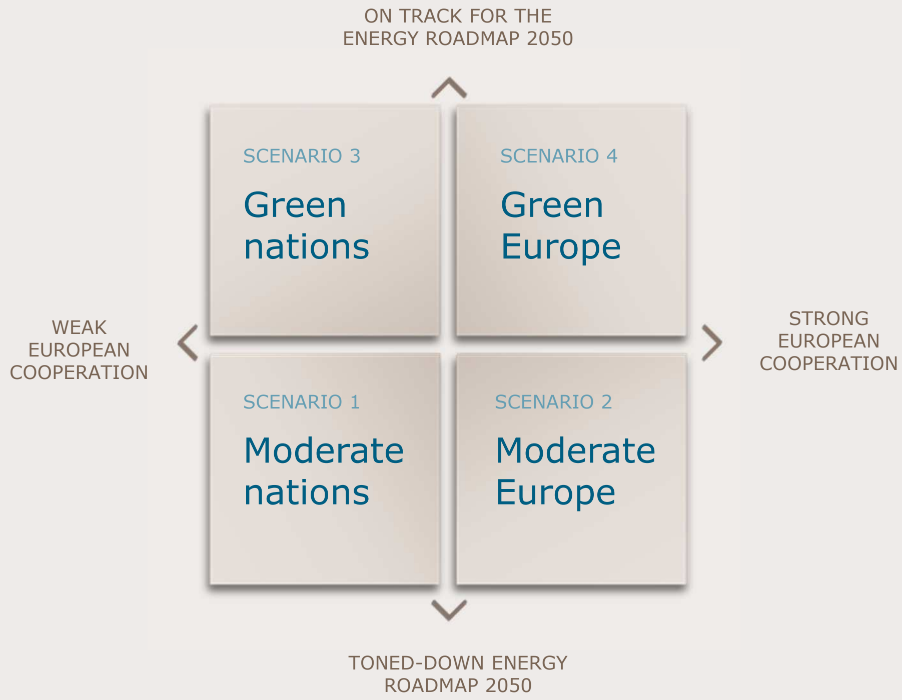
Framework for the energy scenarios

Changes in the surrounding countries and in the EU in general have a major impact on the development of the Danish energy system – in terms of common framework conditions and laws and climate and renewable energy objectives. Energinet.dk's energy scenarios are therefore based on the ENTSO-E scenarios. ENTSO-E is the European cooperation organisation for electricity transmission system operators, and its scenarios primarily describe the possible development of the electricity sector from a European perspective.

The four scenarios are based on the two dimensions in the ENTSO-E scenarios – international integration and environment focus. To be able to apply the scenarios in a Danish context, Energinet.dk's scenarios have been extended in relation to the ENTSO-E scenarios to include several sectors such as gas, district heating, transport and industry. The assumptions for solar and wind power and power stations have also been updated.

To ensure the scenarios can be used within a broader analysis context, Energinet.dk has given high priority to the scenarios being probable and consistent, and reflecting relevant trends. We have therefore consulted relevant stakeholders and advisors in the area of energy and climate change policy, and their input has influenced our scenarios for tomorrow's energy system.

The result is four descriptions of how the Danish energy system might look in around 2030.

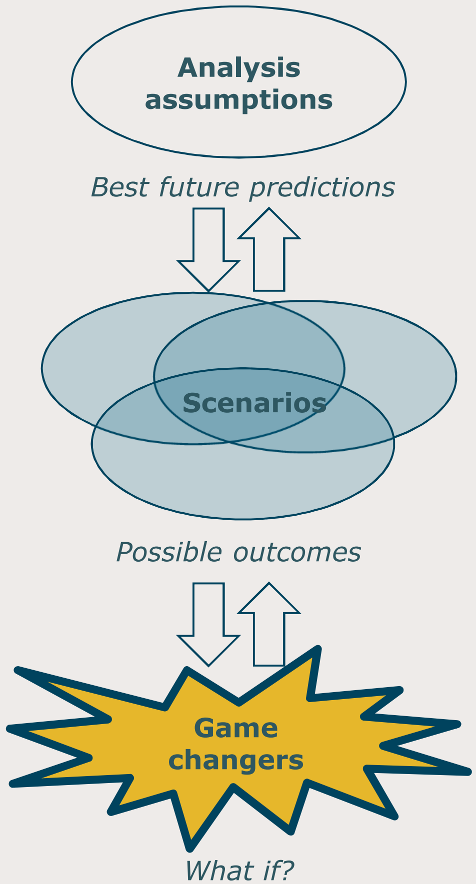


Use of scenarios within Energinet.dk

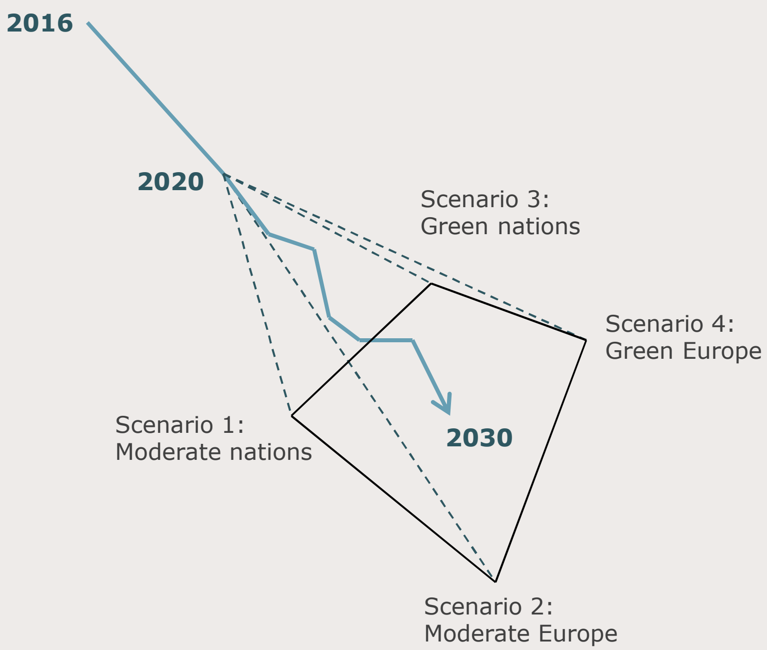
Outcomes and greater robustness
Energinet.dk publishes a set of assumptions each year showing Energinet.dk's best predictions for the future and providing a basis for all analyses and decisions in Energinet.dk. The scenarios supplement these analysis assumptions. The primary aim of the scenarios is to provide perspectives on alternative future trajectories, which can be used for discussion and as input to analyses of the future energy system. The scenarios can stress test the energy system and subject it to widely varying conditions. This allows the robustness of the conclusions from the analyses to be checked. For example, how might the deployment of a new technology interplay with the rest of the energy system? The scenarios are at a more general level than Energinet.dk's analysis assumptions, and are not used directly in business cases for investments. The role of the scenarios is to provide a broader perspective in future business cases.

Wider perspective for grid development
The scenarios will be used in connection with Energinet.dk's coming Network Development Plan to create a perspective plan showing possible alternative developments in the electricity transmission grid.
The perspective plans contribute to the preparation of robust solutions for an uncertain future during the project maturation and detailed planning stages. The first perspective plan is expected to be published in mid-2017.

International planning
Energinet.dk plays an active role in the ENTSO-E European TSO cooperation organisation. In relation to development and planning for the transmission system, Energinet.dk contributes to regional and pan-European network development plans, including ENTSO-E's Ten Year Network Development Plan (TYNDP), which maps potential new international connections in Europe. Using scenarios based on ENTSO-E's scenarios ensures closer coordination between the national and European network development plans.



Energy scenarios towards 2030



Energinet.dk's analysis work looks towards 2050, with a special focus on 2030. It targets the complete future energy system in Denmark and its neighbouring countries. The scenarios are based on modelling and analysis results for 2030.

The scenarios therefore only encompass a certain number of possible developments and adaptations towards the future. The way forward is uncertain, and we need to consider this uncertainty. Developments and events which do not fit into the four scenarios are evaluated in the analyses as potential 'game changers' that can fundamentally change our expectations of the future energy system.

By laying out possible outcomes and testing potential game changers, we can ensure the worldview which serves as a basis for development reflects the short-term and long-term future reality we will face as closely as possible.

The four scenarios are described below.

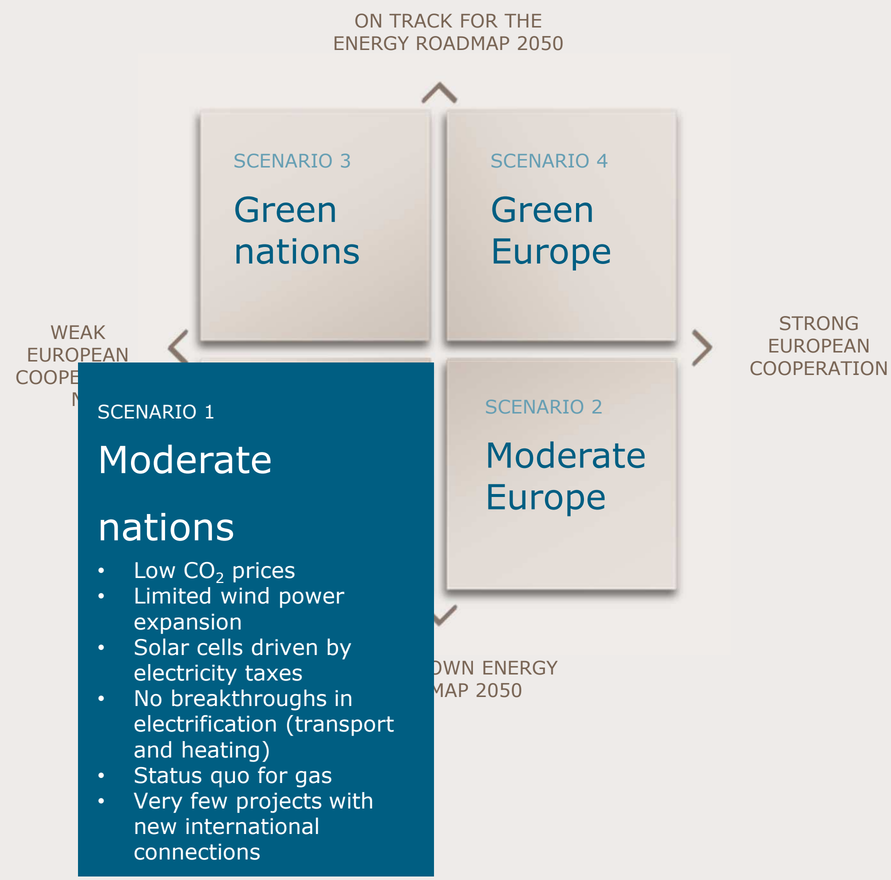
There are links to background material on page 27.

Scenario 1: Moderate nations

The 'Moderate nations' scenario represents a world where EU cooperation is slow. Changes to legislation and framework conditions to promote the generation and use of green energy occur very slowly, as other areas have higher priority politically. Uncertainty about future framework conditions, low electricity prices and limited economic growth slow investment in all electricity-generating technologies. Rising costs of subsidising new green electricity generation combined with low electricity prices mean that the expansion of green electricity generation is reduced to a very low level. Only 600 MW net of wind power is added from 2016 to 2030. During the same period, 1500 MW of solar cells are installed in response to high electricity prices for end customers due to taxes. A third of these have battery backup.

Electrification of energy services such as transport and heating is very slow, and the limited energy optimisations mean that the total electricity and energy consumption stagnates or increases. The gas sector is largely unchanged. Houses heated using gas are converted at a moderate pace, the biogas subsidy is phased out and new gas exchange connections to Poland and Norway are not established.

The energy policy agenda is to formulate national subsidy schemes to ensure sufficient electricity generation capacity to cover local peak loads. In practice, this means the retention and maintenance of steadily aging generating plant and grid. Energy system solutions are based on a self-sufficiency mindset, without coordination in the European context. The establishment of new international connections is limited by a poor investment climate, placing higher demands on project yields.



Impact of 'Moderate nations' scenario on the individual stakeholders

Ordinary citizens

Energy is given little attention. Electricity is perceived as expensive due to taxes. If a gas or oil-fired boiler breaks down, it is replaced with a new gas-fired boiler – where possible. Otherwise a new wood pellet boiler is chosen. Private solar cell owners purchase batteries to exploit solar energy behind the electricity meter. When vehicles need to be replaced, there are only a limited number of electric vehicles available and the price is too high for most people. Only 3 percent purchase an electric or hybrid vehicle.

Electricity and gas companies

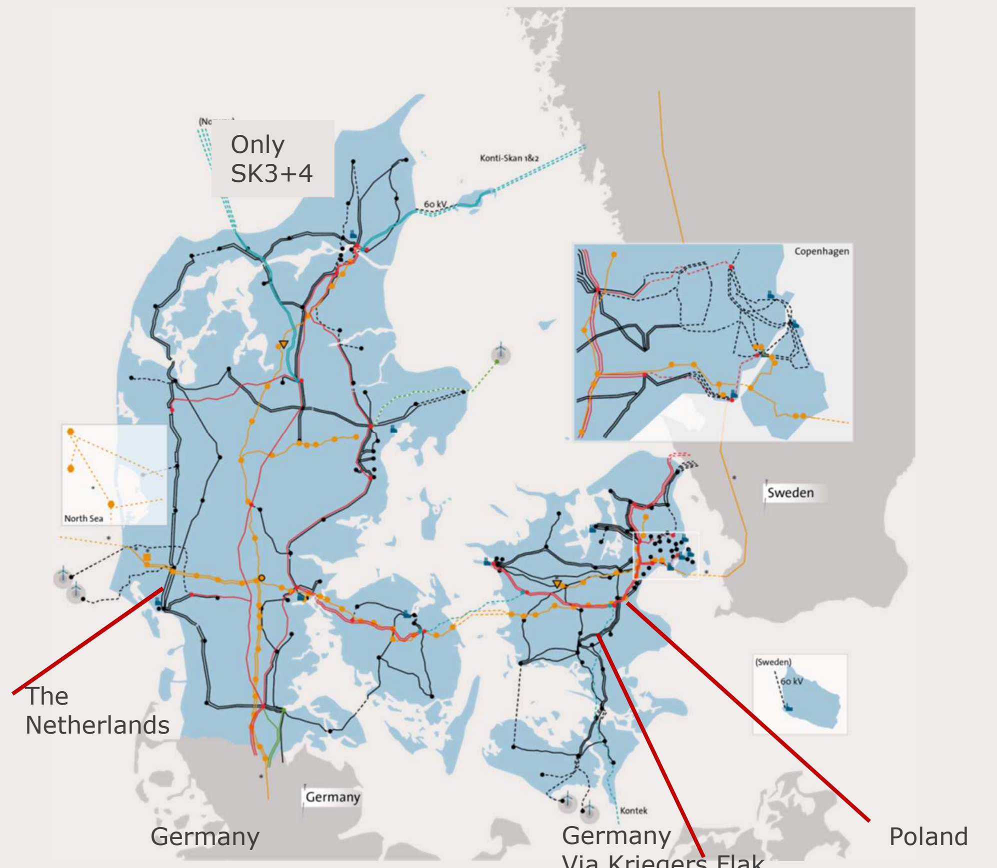
It is difficult to establish new international connections. Several planned projects are not implemented due to uncertainty about economics and framework conditions. To maintain security of supply, existing power stations are kept in service as long as possible and a new interconnection to Poland is built as an extra option for electricity import.

Cities and towns with CHP plants

Focus on the use of biomass for heating continues. Payment offered for keeping electricity production capacity available. The remaining coal-fired plants are allowed to continue operations as long as possible.

Investors in wind and solar power, biogas and power stations

There are few opportunities for investment in new wind power in Denmark. Small CHP plants can be purchased and offered as reserves or receive a capacity charge. Subsidy schemes for biogas are phased out and new biogas plants are therefore no longer built.



Expanded international electricity and gas transmission connections in the scenario

Gas Electricity

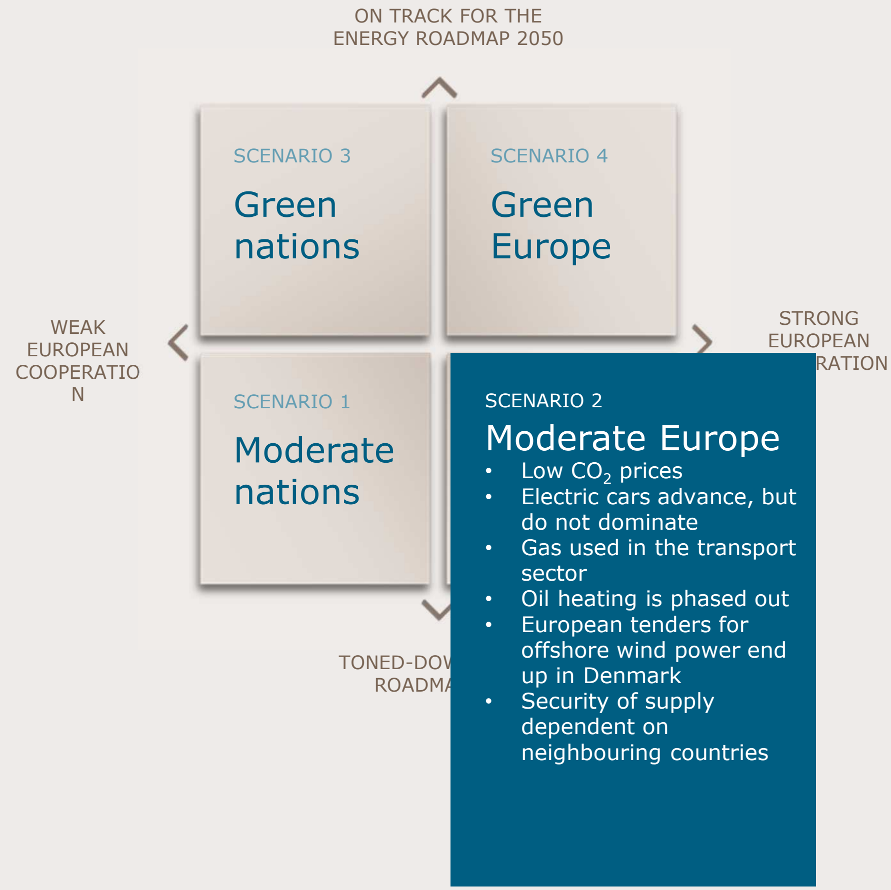
Scenario 2: Moderate Europe

There will be no pronounced green transition in the period up until 2030. Despite repeated declarations of intent at the International and EU level, most countries only implement a few new initiatives to promote renewable energy (RE) after 2020. Investment stagnates due to uncertainty about future changes to regulations.

The international focus is on ensuring the energy system is made more cost-effective instead. For example, agreements on shared ancillary plant, harmonised taxes and gas market liberalisation and market coupling. Towards the end of the period, it becomes clear that Europe must again accelerate the move towards an energy system without carbon emissions. This leads to a number of initiatives which promote central expansion using the cheapest CO_2-neutral generation technologies – biomass, solar cells and wind power. Offshore wind power is tendered at the European level, which means that there is a total of 4,500 MW of offshore wind power in Denmark in 2030.

Only a few national initiatives are implemented in Denmark to ensure new investment in the energy sector from 2020 to 2030. Peak-load capacity is shared between several countries, leading to a reduction in thermal capacity in Denmark. Denmark is completely dependent on neighbouring countries for security of supply at all hours, providing good economic conditions for new international interconnectors.

The Smart Grid is used to control household heat pumps. Oil-fired boilers have been phased out completely in favour of heat pumps and wood pellets. Natural gas is still used directly for household heating. Electric vehicles are on the rise. From 2025, 25 percent of all new cars are electric or hybrid. Gas with green certificates is increasingly used in buses, ships and trucks.



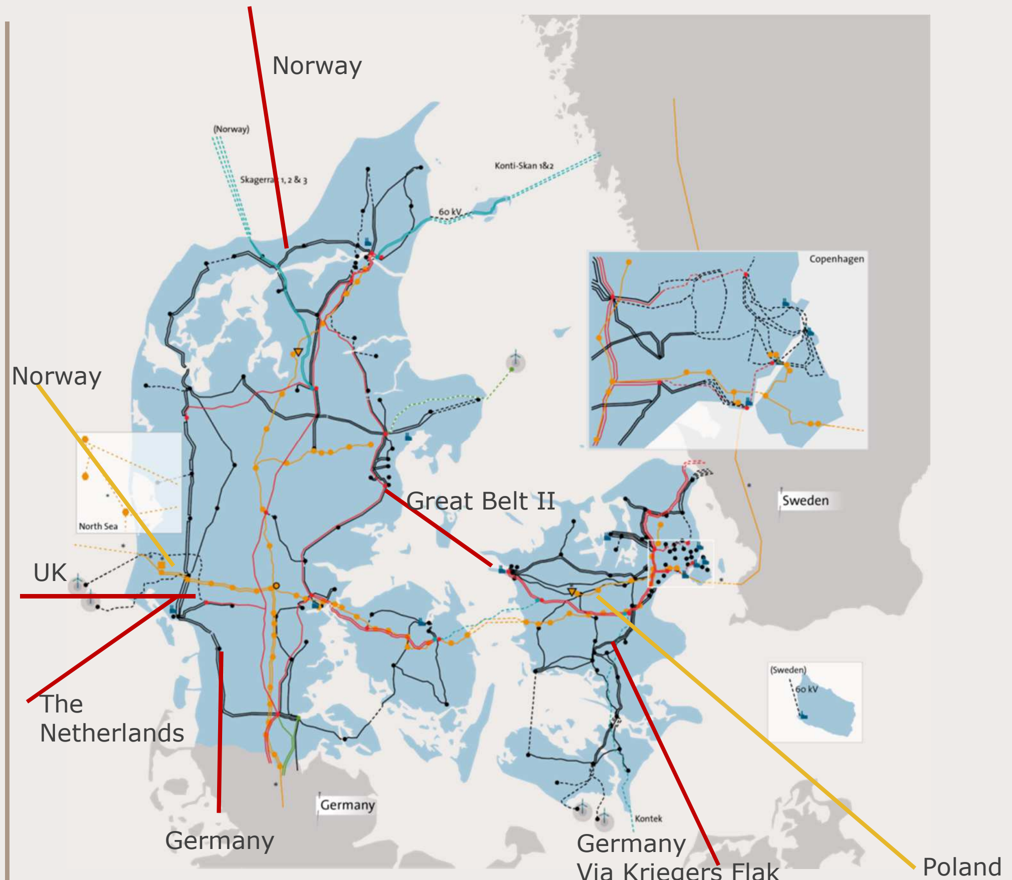
Impact of 'Moderate Europe' scenario on the individual stakeholders

Ordinary citizens
Electricity and heating taxes have been harmonised. For the citizen, this means that district heating, heat pumps or gas are all equal forms of heating. Oil-fired boilers have been replaced by heat pumps, in particular. When vehicles need to be replaced, there is a fairly large selection of good electric and plug-in hybrid vehicles. After 2025, 25 percent choose to buy an electric or hybrid car.

Electricity and gas companies
A new gas pipeline is built from Denmark to Poland, and a connection between the Danish and Norwegian North Sea fields, improving the security of supply for gas. Electricity grid companies have to establish connection and transmission capacity which can handle the offshore wind power capacity in Denmark being more than doubled. This means that all Energinet.dk's planned international connections are built, as well as an additional connection between Eastern and Western Denmark, and the interconnection to Norway is maintained at its current capacity. Security of supply has become a regional matter, and balancing and reserves might just as easily be located outside Denmark as within.

Cities and towns with CHP plants
The use of biomass for combined heat and power will continue in the cities that have already invested in biomass conversion or new capacity. Gas-fired power stations enjoy better conditions, and the remaining coal-fired power stations are therefore converted or replaced with gas facilities.

Investors in wind, solar power and power stations
Denmark has good conditions for offshore wind power and there are several EU tenders for offshore wind capacity that end up in Denmark.



Expanded international electricity and gas transmission connections in the scenari

Gas Electricity

Scenario 3: Green nations

The EU maintains its goal of reducing 80-95 percent of greenhouse gas emissions towards 2050. There is slow progress on international agreements, and like Denmark, each country pursues its own national action plan. There is therefore a strong focus on using wind and solar power locally, through new flexible energy consumption for heating and transport and by implementing battery systems and other types of local energy storage.

It is relatively expensive to achieve climate goals due to strong resistance to transmission lines for European integration of the energy supply. There is resistance in the member states to establishing offshore wind farms, if the electricity generated is exported and thus supplies other countries with renewable energy. There is also resistance to establishing power corridors which can integrate wind power throughout Europe.

The gas network plays a key role in handling green gas, particularly in local areas. Market solutions allow natural gas to be supplied to member states, but international green gas certificates are not widespread.

Denmark is striving to reach 100 percent renewable energy based on wind and solar power and biomass. Solar cells have a prominent role due to their low price and easy integration into the surroundings. Electricity and gas are exported where there are surpluses and sale opportunities, but RE capacity is not being built in Denmark to secure the supply in other areas in Europe etc.

Security of supply is handled at the national level using backup capacity, e.g. in the form of peak-load power stations, CHP plants and gas backup for heating.

Impact of 'Green nations' scenario on the individual stakeholders

Ordinary citizens

Denmark has worked to be at the forefront of the green transition, and this effects everyday life for ordinary citizens. Heating outside district heating areas typically uses heat pumps, and some home-owners with a natural gas boiler have purchased supplementary heat pump units so they have a flexible electricity/gas hybrid solution. Many families have an electric vehicle, and half of all new vehicles from 2025 are electric. Car sharing schemes in towns and cities are popular and based on electric cars. Most people have solar cells, and it is very easy to buy and obtain financing for solar cells.

Electricity and gas companies

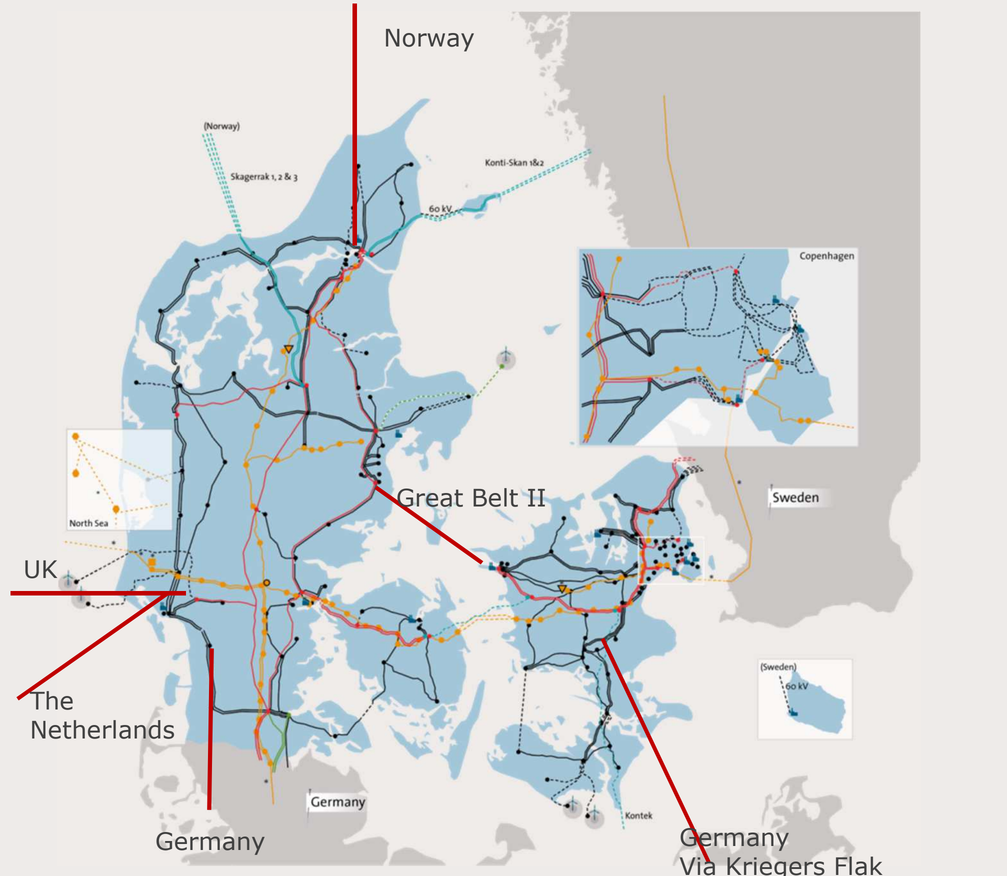
Gas and electricity transmission and distribution systems are being expanded with rapid charging stations and grid connections to fuel factories, biogas plants and petrol stations etc. Smart Grid solutions have been developed for electricity, gas and heating, and electricity consumption is settled on online markets to ensure cost-effective power balancing. Consumers choose and pay for their own level of security of supply.

Cities and towns with CHP plants

Many CHP plants have joined forces with biogas plants and handle both household and commercial waste.

Investors in wind, solar power and power stations

Many wind turbines have been erected in the open landscape. This has led to cheap energy for Denmark, and is therefore generally accepted. Players want to co-own energy production in many areas. Investment companies have therefore had to develop products that balance between cooperative ownership and financial energy companies.



Expanded international electricity and gas transmission connections in the scenari

Gas Electricity

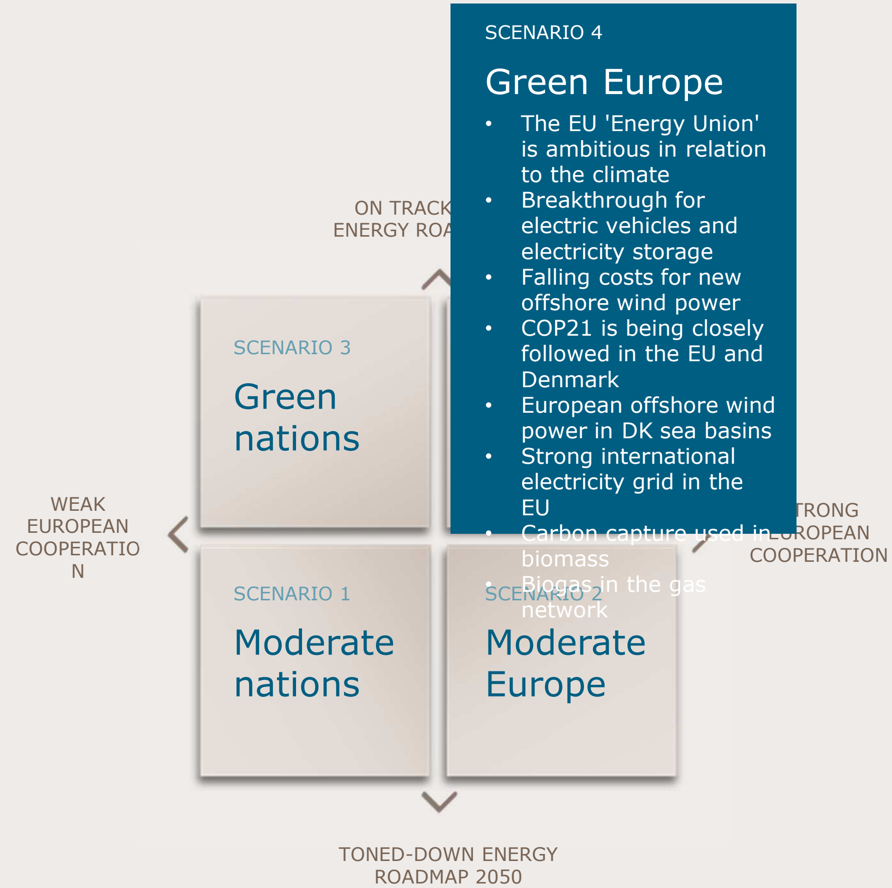
Scenario 4: Green Europe

Pronounced weather phenomena attributable to greenhouse gas emissions have forged international agreement on ambitious efforts to achieve the reduction targets set in Paris at COP21.

There is consensus in the EU to work towards an 80-95 percent reduction in greenhouse gases by 2050, so that Europe can lead the way in the green transition. This means that renewable energy resources in Europe are being optimised with a high degree of specialisation, such that areas with good conditions for RE can export energy. Northern Europe has particularly good conditions for wind power, both onshore and offshore. Together with an improved electricity and gas transmission grid, energy is distributed in Europe, resulting in an energy supply with competitive green energy. Carbon capture and storage (CCS) in biomass or for use in renewable fuel production (CCR) is gaining steam.

Denmark's objective of generating more renewable energy than is consumed in the energy sector is exceeded by the EU's vision of a transition to RE. Denmark is at the centre of one of Europe's most highly wind power dominated zones. The Nordic region also constitutes a central storage facility with hydroelectric power stations. The gas system is also used to handle the transportation of RE Gas from the North Sea region to energy storage facilities and to industrial regions in central Europe.

In Denmark, the national green transition is being transformed into a European transition in 2020-2030. Effective integration of RE electricity, biofuels and heating ensures a competitive energy supply with green energy. Security of supply is maintained through European initiatives and consumer disconnections, and the transmission grids for gas and electricity are being expanded to handle the large volumes of RE.



Impact of 'Green Europe' scenario on the individual stakeholders

Ordinary citizens

The EU's energy union has made Europe a global leader in green energy supply, and Denmark is at the forefront of this trend.

For ordinary citizens, this means that virtually all new solutions are green. Most European towns and cities do not allow vehicles with engine exhaust gases to be driven within their bounds, so since 2025, practically all sales are for electric or plug-in hybrid vehicles.

Electricity and gas companies

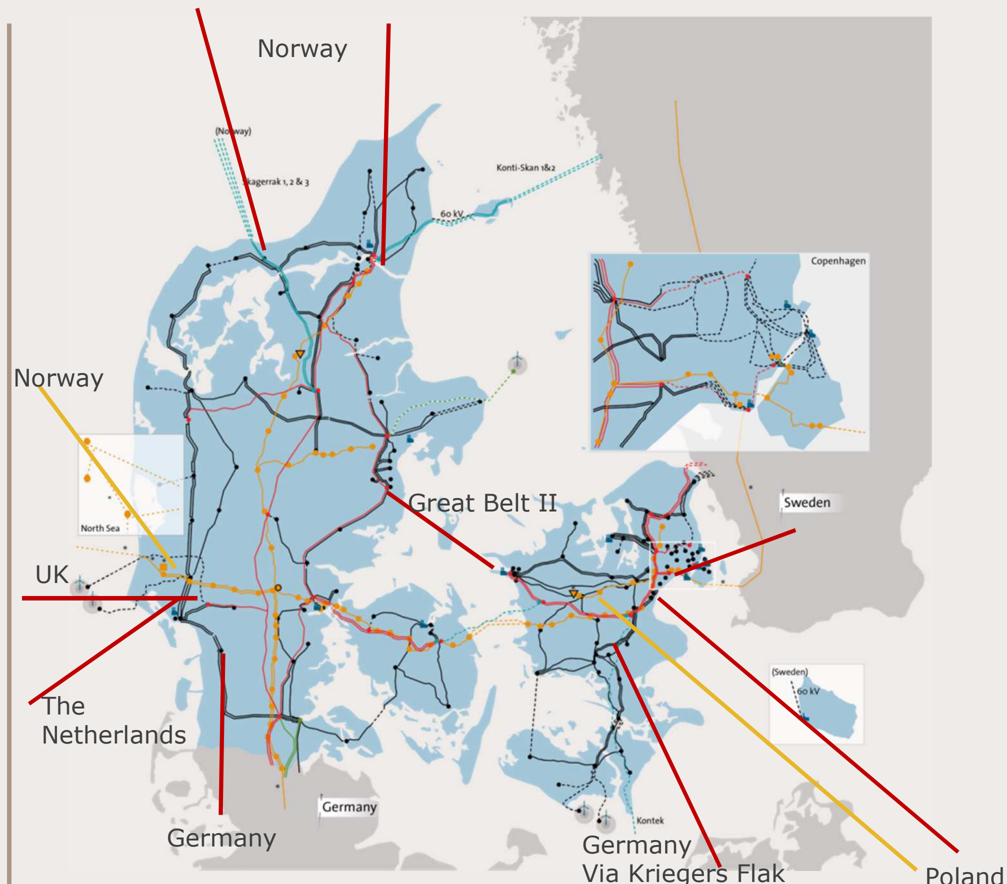
Smart Grids have been established in the EU based on a European standard, and the networks are often operated by European companies. International connections across Europe are being strengthened. Due to expansion of RE gas production and electric vehicle rapid charging stations throughout Denmark, the electricity and gas networks needs to be strengthened at the DSO level.

Cities and towns with CHP plants

In step with the EU's harmonisation of regulations across countries, there has been a greater focus on towns and cities as the entities responsible operationally for generating green energy, waste management etc. CHP units are therefore being transformed into the 'energy centres' of many towns and cities, pooling the energy activities still occurring at the local level.

Investors in wind, solar power and power stations

Many large tenders for RE electricity are being held at the EU level, covering offshore and onshore wind farms and large solar cell parks. EU RE certificates and subsidy schemes have completely replaced the old subsidy schemes, and investors see Europe as one large market with harmonised regulations.



Expanded international electricity and gas transmission connections in the scenario

Gas Electricity

Scenario overview

	Scenario 1 Moderate nations	Scenario 2 Moderate Europe	Scenario 3 Green nations	Scenario 4 Green Europe
Denmark's contribution to fulfilling the EU's energy goals	Small (6°)	Medium (4°)	Large (2°)	Ambitious (1.5°)
Fuel and CO_2 prices	From the IEA's current policies scenarios	From the IEA's current policies scenarios	CO_2 price set locally	From the IEA's 450 ppm scenario
International cooperation	Slow. Primarily national solutions	Close political cooperation	Slow, but with Nordic cooperation	Close political and TSO cooperation. Focus on climate
Framework and market development	Nationally driven	Internationalisation. Harmonisation of taxes and subsidies	Nationally driven. Adjustment to taxes and subsidises for using domestic resources	New market model for energy and power. Harmonisation of taxes and subsidies
Renewable energy (RE) and biogas	Minimal RE and biogas focus	Current subsidy schemes phased out	Extensive expansion	Extensive expansion
Predominant balancing mechanism	International connections (as today) and some flexible consumption	International connections	Flexible consumption. Batteries	International connections and heat pumps and district heating
Energy optimisation	As today	Some focus	Strong focus, electrification	Strong focus, electrification
Transport	3% electric vehicles (half plug-in hybrids)	10% electric vehicles (one third plug-in hybrids) Natural gas and LNG (liquefied natural gas) used for heavy transport	20% electric vehicles. Facility to supply power to grid from electric vehicles (V2G). Far more electric and plug-in hybrid vehicles. Biogas used in heavy transport	35% electric vehicles. Far more electric and plug-in hybrid vehicles. Facility to supply power to grid from electric vehicles (V2G).
Individual heating	15% heat pumps Wood pellets and natural gas	24% heat pumps Oil phased out in favour of heat pumps	57% heat pumps Oil and natural gas phased out in favour of heat pumps	57% heat pumps Oil and natural gas phased out in favour of heat pumps

(continued)	Scenario 1 Moderate nations	Scenario 2 Moderate Europe	Scenario 3 Green nations	Scenario 4 Green Europe
District heating	3% heat pumps	4% heat pumps and electroheat	26% heat pumps. Solar heating with storage. Surplus heat from fuel production	20% heat pumps. Solar heating with storage. Surplus heat from fuel production
Short term flexibility in classic consumption	1%	5%	5%	10%
Smart Grid	No	Only for heat. Standardised in the EU.	Yes	Yes
Carbon capture and storage (CCS)	No	No	No	At CHP plants for the production of fuel
Electricity grid development focus	Maintenance TSO & DSO	TSO	TSO and DSO national solutions	TSO and DSO international solutions
International electricity connections	Difficult to implement new and planned projects. Poland	Planned + Great Belt II and expansion toward Norway	Planned + Great Belt II and expansion toward Norway	Planned + expansion in Sweden, Norway and Poland
International gas connections	No new connections	Between the North Sea and Poland via Denmark	No new connections	Between the North Sea and Poland via Denmark
Electricity generation systems	Some coal	Coal, natural gas, nuclear power in Europe, decentralised thermal power reduced	Coal being phased out. Large-scale storage using batteries etc.	Coal being phased out, natural gas for backup power and extensive wind and solar power. Large-scale storage using green gas etc.
Technological development			Extensive development of batteries for vehicles and local storage. Solar cells are very cheap. Pilot plant: Power 2 gas and thermal gasification for fuel production	Extensive development of batteries for vehicles and local storage. Focus on large units such as offshore wind turbines. Power 2 gas and thermal gasification for fuel production
Use of biomass?	Heating and CHP	Heating, CHP and some biofuel	2G fuel for local objectives	2G fuel supplemented by P2G produced for the international market. Generates heat for towns and cities

Selected scenario results

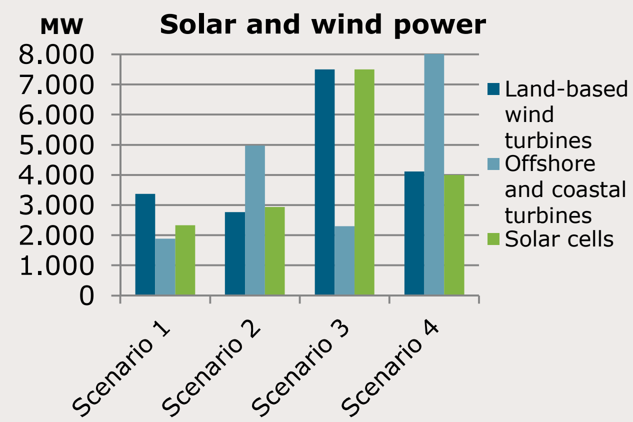
First results from simulating the scenarios

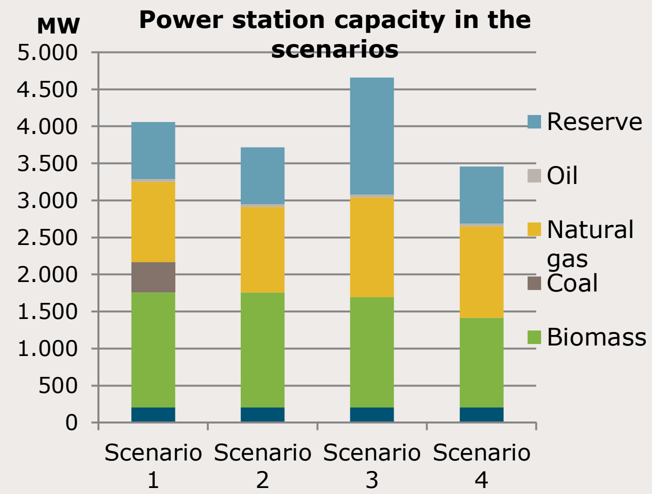
Electricity generation capacity in the scenarios

Scenario 2 (Moderate Europe) and scenario 4 (Green Europe) are European scenarios where solar and wind power and thermal power stations will be expanded to meet European needs rather than national needs. This entails greater renewable energy expansion in the European countries where it can be done best and most cheaply for the total European energy system. For Denmark, it means a major expansion of offshore wind power in scenario 4. The need for thermal generation to cover peak loads when wind or sunshine fails is also coordinated at European level. Power station capacity is therefore less in Denmark in both scenario 2 and 4. Scenarios 1 and 3 are more national scenarios, where RE expansion and security of supply are national concerns.

Scenario 3 (Green Nations) and 4 are both scenarios where wind and solar power are expanded to achieve CO_2 reductions. Scenario 3 focuses on solar and onshore wind power, which are both relatively cheap compared to offshore wind power in the scenario. Scenario 1 (Moderate Nations) reflects limited investment in all new generation capacity. Existing planned projects for offshore wind farms and power station conversions to biomass are implemented, but there are very few new projects. There is a minor expansion in solar cells, driven by the economic gains of generating and using power before the electricity meter.

Several of the large central power stations have already been converted to using biomass instead of coal or natural gas (with more conversions planned). Once a plant has been converted, it will most likely continue operation using biomass for a number of years into the scenario period. Biomass capacity is therefore much the same in all scenarios. In scenario 1 and 2, natural gas is used as a source of heat generation with relatively low carbon emissions. In scenario 3, a number of local plants are retained as a low-cost source of reserve power. Coal continues to be used in scenario 1, and some coal-fired plants are retained in scenario 3 as a reserve. The others are either closed or converted. It has not been investigated whether the scenarios fulfil the objective of no more than 20 minutes' electricity supply outages per year.





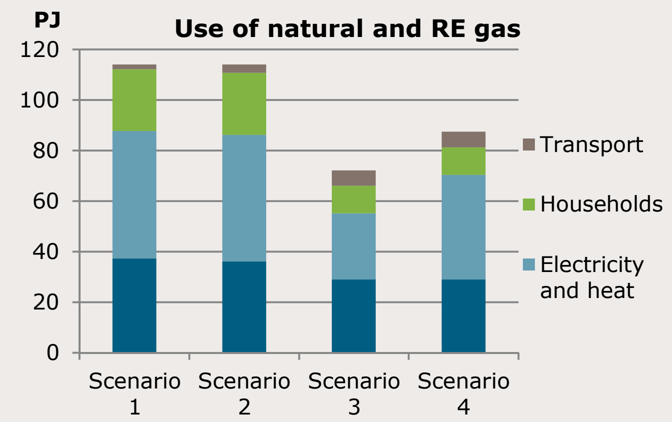
Electricity and gas consumption in Denmark in the scenarios

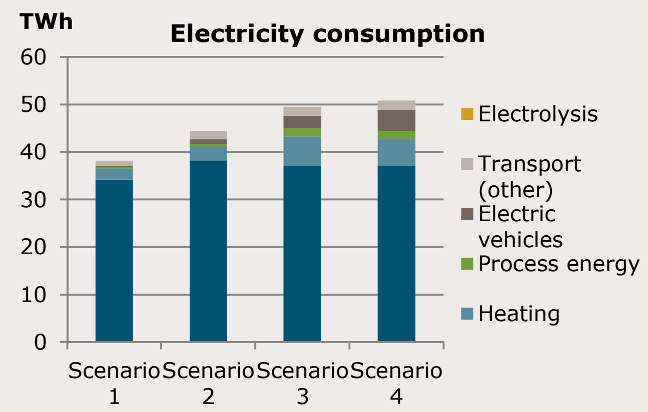
Consumption of natural and RE gas
Natural and RE gas is used in all scenarios for heating, commercial activities and CHP. RE and natural gas is also used for bus, ship and truck transport. Primarily natural gas in scenario 1 and 2, with more RE gas in scenario 3 and 4. There is surplus RE gas in the scenario 3 and 4, which can be used for transport, fuel production or as a substitute for natural gas.

Gas will play a lesser role in scenario 3 and 4. Household and commercial heating will be converted to heat pumps and – to a lesser extent – biofuel. Some industrial process energy will be converted to electricity and biofuel. CHP plants will also be replaced by heat pumps and biomass heating. However, gas will still play a relevant role, as it is expected to serve as a peak-load fuel when electricity prices are high. Heat from gas-fired peak-load units is used to relieve electric boilers and heat pumps when the electricity price is high or there is insufficient electricity generation.

Electricity consumption
Electricity will be used to an increasing extent in all scenarios and particularly in scenario 3 and 4, where there will sometimes be extensive RE production from solar and wind power. New electricity consumption derives from heating using heat pumps and electric boilers, electricity that replaces process energy in industry and transport. New data centres are also expected to use a significant amount of power in the scenarios – particularly in the green scenarios. To a lesser extent, electricity is also used for electrolysis to produce hydrogen, used in the production of RE gas and green fuels.

Common to many new applications is the fact that they can be made flexible to varying degrees. For example, large heat pumps and electric boilers in towns and cities can be stopped and replaced with heat from gas if there is no energy available in the power grid.

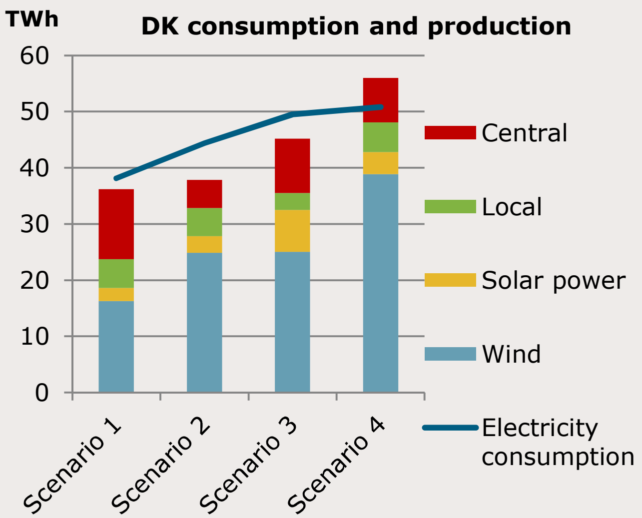


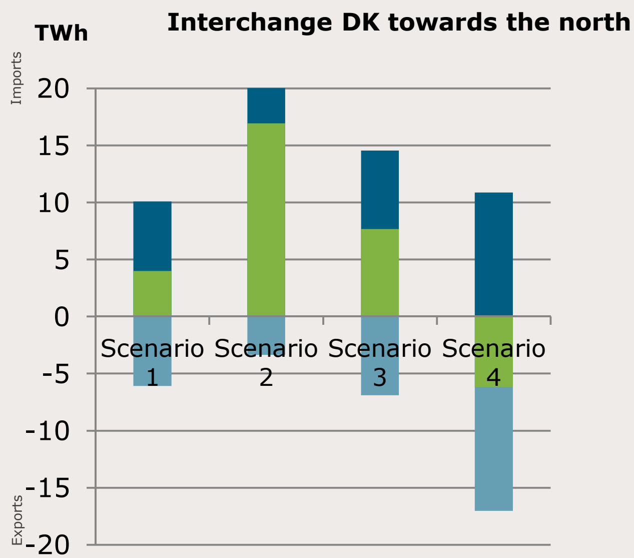


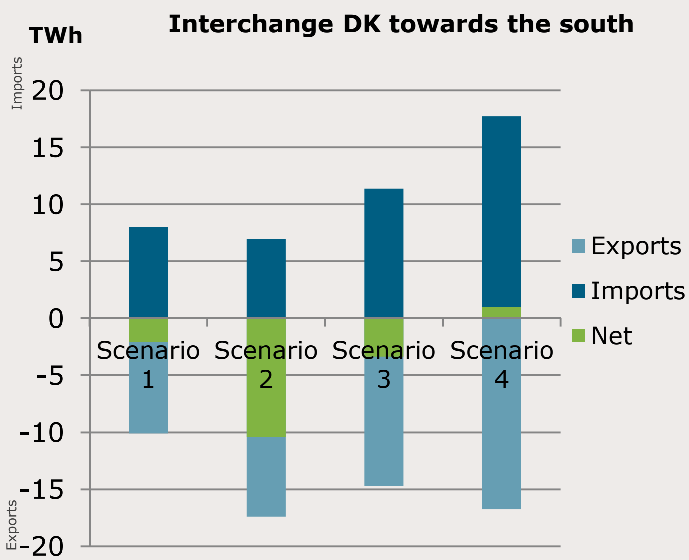
Generation, consumption and exchange of electricity in the scenarios

Generation at power stations and exchanges with neighbouring countries will depend not only on what happens in Denmark, but also on developments in neighbouring countries and prices of fuels and CO_2. Electricity prices in other countries and fuel prices have been defined in the scenarios based on the ENTSO-E scenario models from the TYNDP16 project. This is helping to drive the transfer of electricity from the Nordic countries (Norway and Sweden) to Europe south of Denmark (England, the Netherlands, Germany and Poland) and vice versa. All scenarios thus show large transfers of electricity through Denmark. In scenarios 1 to 3, electricity moves from north to south on the whole. In scenario 4, Denmark exports more electricity to the Nordic countries on average than is imported, and exchanges with the south are very small on average.

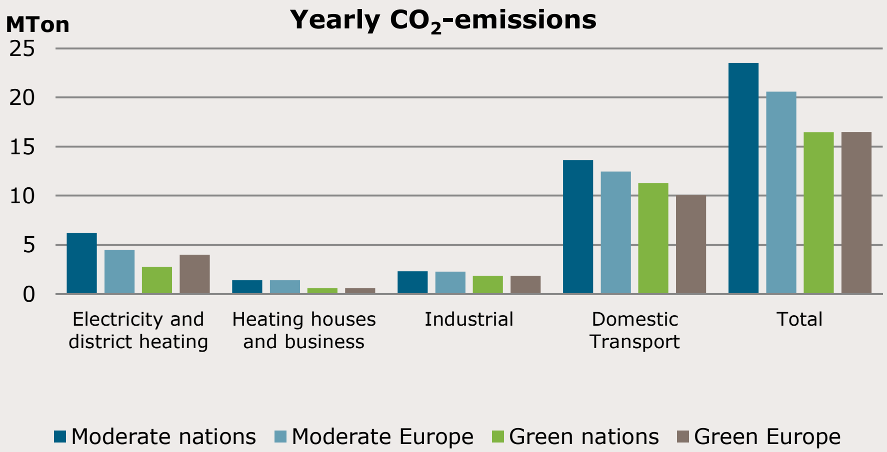
The exchange varies from hour to hour depending on consumption, wind and solar power and the operation of conventional and hydroelectric power stations in Denmark and neighbouring countries. The graphs of the annual interchange below thus conceal large daily fluctuations.

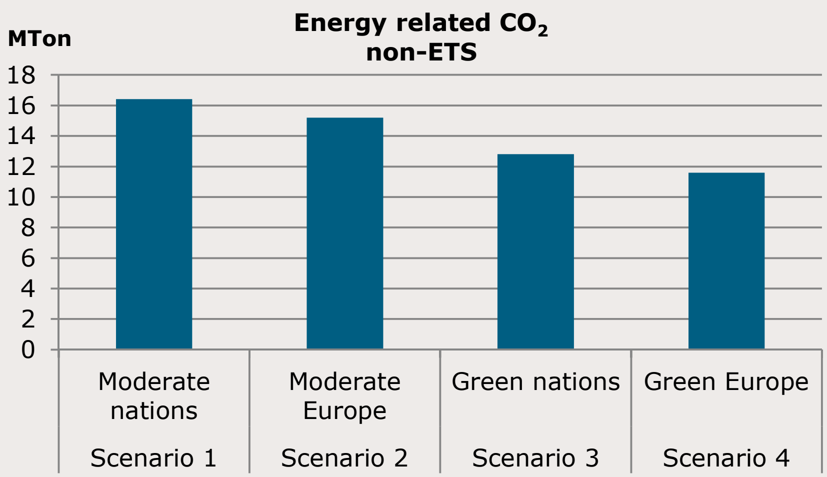






CO_2 emissions from energy use in the scenarios





The four scenarios only describe CO_2 emissions derived from energy use within the emissions trading system (ETS) and CO_2 emissions derived from energy use outside of ETS. Emissions from agricultural etc. are not covered in the scenarios.

As a part of the EU's burden-sharing, Denmark is expected to be assigned a CO_2 reduction target for non-ETS sectors of 39 percent in 2030, compared to 2005. For the energy-related part of non-ETS CO_2, i.e. excluding emissions from agriculture etc., the reductions for the 'Green Europe' and 'Green nations' scenarios are less than this value. However, there is no specific target for energy-carrying non-ETS emissions.

CO_2 emissions from agriculture and other sectors outside energy consumption are not described in the scenarios. It is therefore not possible to determine from the scenarios whether Denmark is generally fulfilling its obligation. Lower energy-related emissions might be outweighed by higher emissions from the non-energy sector or vice versa.

With total energy-related CO_2 emissions of approx. 16 million tonnes in 2030 in the two green scenarios, Denmark is on track towards a long-term goal of fossil fuel independence in the energy supply. However, the transport sector is still a relatively high CO_2 emitter.

Game changers

Events that can create completely new scenarios and outcomes

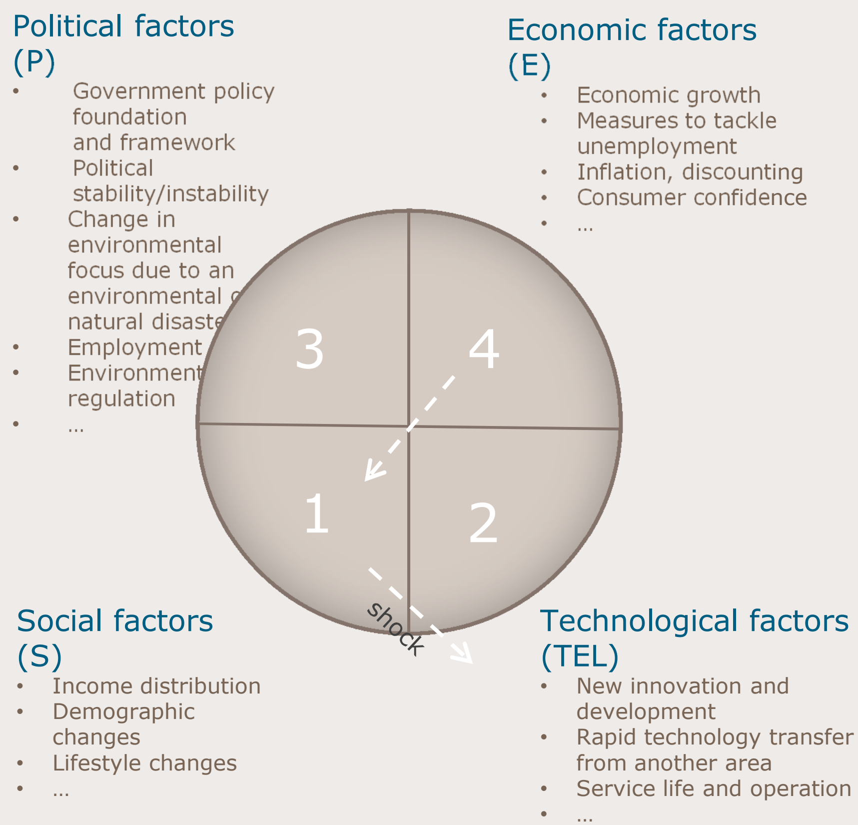
Analysis of game changers

The four scenarios project an outcome space for the energy system up until 2030. The various scenarios are as complete as possible. However, local conditions are continually changing. Changes in the surrounding conditions in terms of policy frameworks, technology, fuel prices, consumer preferences etc. often come abruptly. These types of external 'shocks' can sometimes radically change the direction for development and operation of the system, and they are therefore called 'game changers'.

A game changer can move the entire system in the direction of another scenario. For example, a major environmental disaster might increase focus on green solutions. Or international crises can reduce confidence in international cooperation and give rise to a national focus. Based on a 'PESTEL' analysis, a number of potential game changers have been identified which are seen as having the potential for a major impact on the system. The general development trends the analysis is based on are shown in the figure on the right. The various items are described in more detail on the following pages.

The list is not exhaustive, but presents some key focus points that can be taken into account when using the scenarios. For example, through supplementary analyses of the robustness of the various strategic initiatives in the energy system.

A number of game changers have been selected in the following section, each of which could cause major upheaval in the energy system.



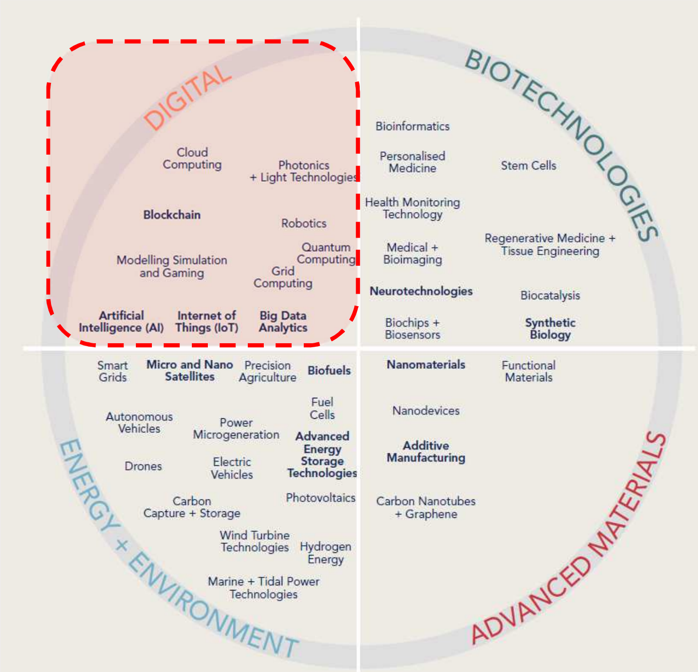
Game changer: Digital development creates new market solutions

Digital development is making new forms of business and trade possible, which can cause major changes in the energy sector and change the roles in the electricity market. Electricity micro-trading means that all consumers – and even small units – can be their own balance responsible party and avoid having to buy electricity via an intermediary. The technology allows small units (heat pumps, electric vehicles, solar cells, refrigerators etc.) to trade directly via web services. An electric vehicle could buy surplus power from the neighbour's solar cells, a wind turbine or via the day-ahead or intraday market. Balance settlement can be done directly on a real-time market, using exclusively digital payments with digital currencies, such as Bitcoin.

There are a number of general digital development trends from other sectors that can lead to this situation. Cheaper energy metering, secure data communications, data storage in the cloud and digital financial transactions are making new market solutions with direct micro-trading possible. For example, this could allow a local renewable energy surplus to be used in the distribution grid. Appliances can be sold including the supply of green energy.

The solutions will lead to the transaction costs of energy trading, measuring and settlement being significantly reduced. This means that electricity-consuming units of any size can participate flexibly and dynamically in the market, and regional congestion in the electricity grid can be handled in the market using 'nodal pricing' principles. This is overall an advantage for the electricity system, but it may prove difficult for each TSO to get an overview of generation, consumption and trade in electricity at the lower voltage levels.

For electricity traders and BRPs it will lead to much trading and balancing activity directly between the end user and power exchange. Electricity traders must therefore make major changes to their market products in order to continue to play a role in relation to customers who are able to trade directly on exchanges and act as their own BRPs. Electricity trading will become a service on par with finding a deal on a holiday home or booking a taxi.



Source for figure: An OECD Horizon Scan of Megatrends and Technology trends in the context of future research strategy, 2016

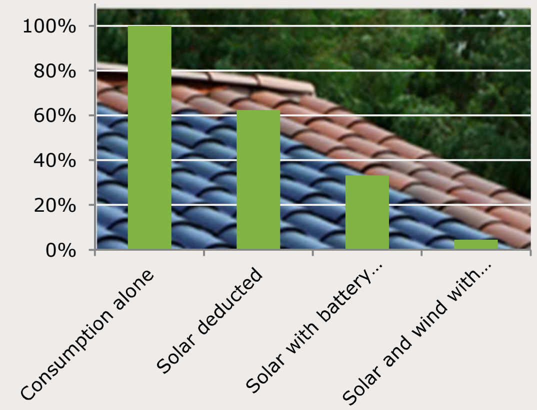
Game changer: Huge 'off grid' wave with local solutions

Private electricity and heat generation can largely move from collective supply to auxiliary supply at a local level. This trend is initially evident in electricity consumers' investment in solar cells and later in battery technology and possibly wind power or micro-CHP. If you utilise solar power, a battery and a local wind turbine, it is practically possible to completely disconnect from the grid. Excess electricity the battery cannot handle can be used for charging electric vehicles or heating and hot water. The question will be whether consumers disconnect from the electricity grid in a de facto manner by continuing to be connected but only use it occasionally, or completely disconnect from the grid to avoid paying taxes and charges for the grid.

The trend is being driven by falling costs for solar cells, in particular, and battery technology, and taxes and tariffs levied on energy from the public supply grid. The trend is being intensified by scepticism regarding future security of supply and climate targets, and the desire for a secure and inexpensive heating and electricity supply.Consumers fear a market trend with high prices and system demands for consumer flexibility in peak-load situations, and may therefore choose to establish their own solutions.

The off-grid wave has slightly varying consequences. Up to one-third of the annual electricity consumption could disappear from the grid. This will first of all impact on payment for the grid, which is currently financed through tariffs and electricity use. To compensate for the decline in tariff income, tariffs would have to be increased, reinforcing the off-grid trend. If consumers actually disconnect from the electricity grid, it will have more excess capacity and less need for further expansion. RE generation connected to the grid can also quickly end up meeting 100% of consumption as consumption declines. If consumers remain on the electricity grid, there is a risk that full consumption will return on particularly challenging days (eg during storms). The electricity system would then have to handle the full energy consumption from earlier times, but might have been adapted to a situation with lower electricity consumption.

Reduction in grid needs due to local solar, wind and batteries



Game changer: Biomass price jump?

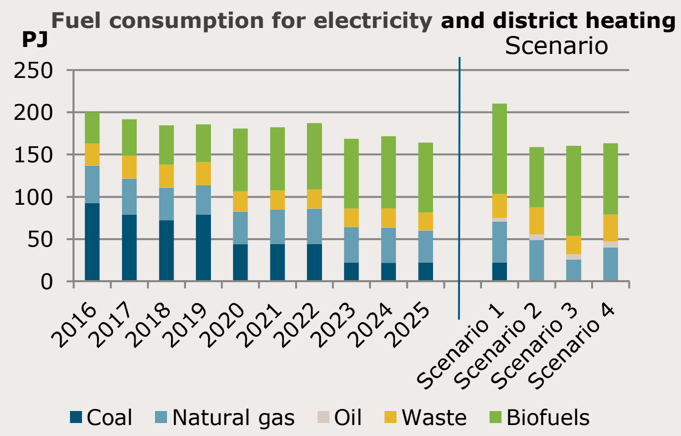
Biomass is expected to account for over 50 percent of the fuel used for electricity and heating in 2025, and this trend is reflected in all scenarios. Such a large share for one type of fuel raises the question: What would happen if biomass becomes unavailable or very expensive? Would it have a major impact on the energy system or emissions?

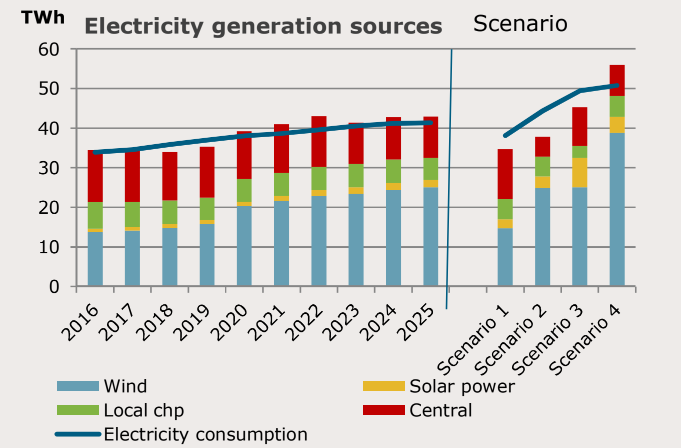
There are several possible trends which could make biomass unavailable or unattractive due to high costs:

- More stringent biomass certification and sustainability requirements
- Competition from other countries or sectors willing to pay more could result in major price increases
- For local biomass: Decreases in biomass production due to changes in crops
- Biomass supplies become unavailable due to unrest or natural disasters
- If biomass is no longer recognised as CO_2-neutral and is subjected to an ILUC factor.

Generally speaking, the energy system can manage without biomass, but it will have significant economic costs, particularly for heating companies and power station owners, and lead to increased emissions:

- For heating customers it will most likely mean a significant increase in the price of heating
- For CHP plant owners it could mean extra costs for alternative fuels and heat sources and greater tax expenses
- For the environment, alternative fuels or heat sources could be coal, oil or gas, resulting in higher emissions. This could mean that emission targets are not reached
- For Energinet.dk, it could mean that electricity generating plant based exclusively on biomass become unavailable. This type of plant only has a total capacity of approx. 120 MW, and biomass is a minor part of the total electricity generation.





Game changer: Zero marginal cost

Given technological development, energy and energy supply will be increasingly a question of the right technology rather than of resources. Supply activities and energy production will be characterised by very large investment costs and marginal production costs, approaching zero. Examples of this are wind turbines, solar cells, water bores and road systems.

A price set by the market would therefore have to predominately cover the investment costs of production. This raises a price policy problem following the depreciation period and the use of the market price as a signal to market players. Until around 10 years ago, almost all electricity was planned and produced at Danish CHP plants. Today, over 40 percent of our consumption is met from wind power and solar cells. In the not too distant future, 100 percent of our electricity consumption will be generated at marginal costs approaching zero, which will be a challenge for signalling in the market. The price in the market will be set by the price of not using electricity. As a result, existing models for electricity trading may fail.

A private and macroeconomic marginal price approaching zero could be replaced by new market or business models. For example, a model whereby electricity is not sold purely by the kWh but is bundled with other characteristics regarding origin or security of supply could be a realistic alternative. Gradually, in step with a larger share of production at no cost, new business models could arise in parallel with the existing electricity markets, to ensure that power is marketed at the highest possible price.

Fixed price BASIC	Fixed price GREEN	Fixed price GIGA
Unlimited use 3 kW secured supply* RES electricity Fossil-fuel backup.	Unlimited use 3 kW secured supply* Electricity from solar, wind and batteries only.	Unlimited use 9 kW secured supply* RES electricity Fossil-fuel backup.
DKK 699/month.	***DKK 799/month.***	***DKK 1,499/month.***

* In periods with limited electricity supply, consumption is limited to 3kW

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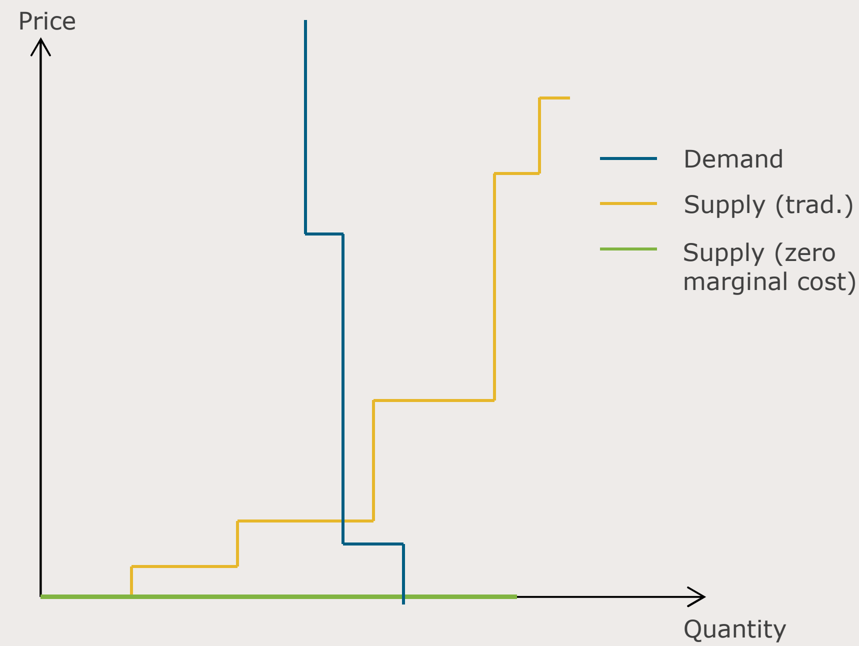
Sample advertisement for a future electricity product?



Background material

Background material for the scenarios in Excel format contains the following:

Electricity consumption
Electricity consumption, including ordinary electricity consumption, heat pumps and electroheat, electric vehicles, data centres and electrolysis for the production of green gas

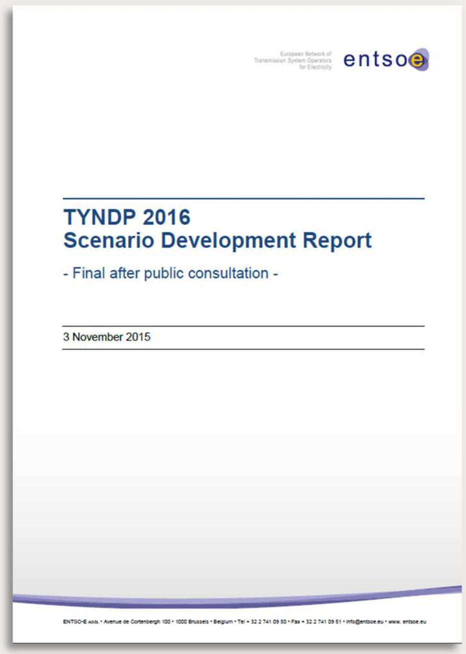
Electricity and CHP generation
Overview of electricity generation capacity from solar and wind power and power stations

International connections
Transmission capacity from Denmark to other countries and between Eastern and Western Denmark

Gas and fuels
Gas consumption, production of green gas, fuel production

District heating
Electric boilers, solar heating, geothermics and heat pumps in the district heating sector.

http://www.energinet.dk/SiteCollectionDocuments/Danske%20dokumenter/Klimaogmiljo/15-08958-152%20Energiscenarier%20Baggrundsmateriale%2004.10.2016.XLSX


entsoe
TYNDP 2016
Scenario Development Report
- Final after public consultation -
3 November 2015

ENTSO-E scenarios for 2030, which are used as a framework for scenarios and describe the situation in other countries.

Link:
https://www.entsoe.eu/Documents/TYNDP%20documents/TYNDP%202016/rgips/TYNDP2016%20Scenario%20Development%20Report%20-%20Final.pdf

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About Energinet.dk's analyser

Energinet.dk is responsible for the security of electricity and gas supply, both now and in future, where much more renewable energy must be included in not just the electricity and gas sector, but the energy system as a whole. Thus, the energy system is facing great changes and there is a need for increased integration in the energy sector.

Energinet.dk takes responsibility for an economically viable transition. To create the foundation for the best possible transition, illustrate outcomes and ensure the value of the large investments to be made, Energinet.dk continuously analyses the development of the energy sector as a whole and separate parts of the energy system.

In general, Energinet.dk uses the same annually updated foundation for all analyses. Among other things, the foundation consists of assumptions about prices, technology data and calculation models.

www.energinet.dk/energianalyser